NONLINEAR FINITE ELEMENT ANALYSIS OF INTEGRAL BRIDGE INCLUDING FOUNDATION SOIL INTERACTION (WINKLER ANALOGY)

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By

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APPROVAL SHEET

This project attached here, entitled " **NONLINEAR FINITE ELEMENT ANALYSIS OF INTEGRAL BRIDGE INCLUDING FOUNDATION SOIL INTERACTION (WINKLER ANALOGY)** " prepared and submitted by **MOHAMMAD SOFFI BIN MD. NOH (GS 15733)** in partial fulfillment of the requirements for the Degree in Master of Science in Structural Engineering and Construction is hereby approved.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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analysis was carried out, which are Winkler's spring analysis, linear analysis and nonlinear analysis. The results show that, the soil nonlinearity has significant effect on the results, where the displacement which obtained form nonlinear analysis is much higher than that obtained from linear analysis and spring analysis.

ABSTRACT

Bridges without expansion joints are called “integral bridges.” Eliminating joints from bridges crates concerns for the piles and the abutments of integral bridges because the abutments and the piles are subjected to temperature-induced lateral loads. This kind of bridges are becoming very popular due to different aspects such as good response under seismic loading, low initial costs, elimination of bearings, and less maintenance. However, the main issue related to the analysis of this type of structures is dealing with the soil-structure interaction of the abutment walls and the supporting piles.

This study describes the implementation of a two dimensional finite element model of integral bridge system which explicitly incorporates the nonlinear soil response. The superstructure members have been represented by means of three-noded isoperimetric beam elements with three degree of freedom per node which take into account the effect of transverse shear deformation.

The soil mass is idealized by eight noded isoperimetric quadrilateral element at near field and five noded isoperimetric infinite element to simulate the far field behavior of the soil media. The nonlinearity of the soil mass has been represented by using the Duncan and Chang approach. In order to study the behavior of integral bridge under varies loading condition including the effect of temperature load, three type of

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CHAPTER 1

1.0 INTRODUCTION

1.1 Introduction of Bridge Structure

Bridge structure built to provide ready passage over natural or artificial obstacles, or under another passageway. Bridges serve highways, railways, canals, aqueducts, utility pipelines, and pedestrian walkways. In many jurisdictions, bridges are defined as those structures spanning an arbitrary minimum distance, generally about 10–20 ft (3–6 m); shorter structures are classified as culverts or tunnels. In addition, natural formations eroded into bridge like form are often called bridges. This article covers only bridges providing conventional transportation passageways.

Bridges generally are considered to be composed of three separate parts: substructure, superstructure, and deck. The substructure or foundation of a bridge consists of the piers and abutments which carry the superimposed load of the superstructure to the underlying soil or rock. The superstructure is that portion of a bridge or trestle lying above the piers and abutments. The deck or flooring is supported on the bridge superstructure; it carries and is in direct contact with the traffic for which passage is provided.

Bridges are classified in several ways. Thus, according to the use they serve, they may be termed railway, highway, canal, aqueduct, utility pipeline, or pedestrian bridges. If they are classified by the materials of which they are constructed (principally the superstructure), they are called steel, concrete, timber, stone, or aluminum bridges. Deck bridges carry the deck on the very top of the superstructure. Through bridges carry the deck within the superstructure. The type of structural action is denoted by the application of terms such as truss, arch, suspension, stringer or girder, stayed-girder, composite construction, hybrid girder, continuous, cantilever, or orthotropic (steel deck plate).

Bridge designs differ in the way they support loads. These loads include the weight of the bridges themselves, the weight of the material used to build the bridges, and the weight and stresses of the vehicles crossing them. There are basically eight common bridge designs: beam, cantilever, arch, truss, suspension, cable-stayed, movable, and floating bridges. Combination bridges may incorporate two or more of the above designs into a bridge. Each design differs in appearance, construction methods and materials used, and overall expense. Some designs are better for long spans. Beam bridges typically span the shortest distances, while suspension and cable-stayed bridges span the greatest distances.

1.2 Design Selection of Bridge

Engineers must consider several factors when designing a bridge. They consider the distance to be crossed and the feature, such as a river, valley, or other transportation routes, to be crossed. Engineers must anticipate the type of traffic and the amount of load the bridge will have to carry and the minimum span and height required for traffic traveling across and under the bridge. Temperature, environmental conditions, and the physical nature of the building site (such as the geometry of the approaches, the strength of the ground, and the depth to firm bedrock) also determine the best bridge design for a particular situation.

Once engineers have the data they need in order to design a bridge, they create a work plan for constructing it. Factors to be considered include availability of materials, equipment, and trained labor; availability of workshop facilities; and local transportation to the site. These factors, in combination with the funding and time available for bridge design and construction, are the major requirements and constraints on design decisions for a particular site.

1.3 Nature of Problem

A bridge should be designed such that it is safe, aesthetically pleasing, and economical. Prior to the 1960s, almost every bridge in the world was built with expansion joints and bearings. These traditional expansion joint/bearing systems has been found to perform more or less as intended conceptually but at the cost of being a high maintenance item, especially for relatively short-span bridges. The primary problem is the corrosion and other physical deterioration of the bridge bearings that occurs with time. They required considerable maintenance, which undermined the economical operation of the bridges. Therefore, integral bridges have been found to outperform jointed bridges, decreasing maintenance costs, and enhancing the life expectancy of the superstructures. Integral abutment and joint-less bridges cost less to construct and require less maintenance then equivalent bridges with expansion joints and bearings.

Because of the increased use of integral bridge, there is now greater awareness of and interest in their post-construction, in-service problems. Fundamentally, these problems are due to a complex soil structure interaction mechanism involving relative movement between the bridge (more specifically, its abutments) and adjacent retained soil. Because this movement is the result of natural, seasonal thermal variations, it is inherent in all integral bridges.

The main issue related to the analysis of integral abutment bridge is dealing with the soil-structure interaction of the abutment walls and the supporting piles. The behavior of the structural components including the piles can either be linear or nonlinear depending on the amount of the applied forces. The behavior of the soil on the other hand is nonlinear. Therefore, the analysis of integral bridge should take into account the nonlinearity of soil behind the abutment and the piles foundation.

1.4 Objectives of Study

The primary objectives of this study are:

1. Investigate the behavior of structural elements of the integral bridge under various load cases through finite element analysis.

2. Study the significance of thermal expansion load induced displacement.

3. Investigate the significance differences and similarities between the Winkler's spring analysis, linear analysis and nonlinear analysis of integral bridges.

1.5 Scope of Study

In order to study the behavior of integral bridge under different of load cases, this study have been carried out within the following scope.

1. Finding a literature review to establish the current state of knowledge with regard to the behavior of integral abutment bridges.

2. Implement finite element analysis for three different type of analysis which is Winkler spring, linear elastic and nonlinear elastic analysis.

3. Descretized the finite element models through the following elements;

   a) Three noded beam bending element

   b) Eight noded isoparametric elements

   c) Five noded infinite elements

4. Loading analysis of integral bridge is based on code of practice, BD 37/88.

5. Collect the actual temperature data based on the Malaysian temperature different obtained from Department of Meteorology Malaysia.

6. Preparation of the actual data required for the nonlinear elastic analysis based on Malaysian soil condition.

7. Analyze the structure and soil media using existing two dimensional finite element program available at Structural Engineering Unit, Civil Engineering Department, Universiti Putra Malaysia.

1.6 Organization of Report

In order to achieve the objectives of this study, this report is implemented and organized as follows.

Chapter 2: Present an overview of integral bridge in order to enhance the current state of knowledge with regard to behavior of integral bridge system, characteristic and type of integral abutment of the bridge. Advantages and problem associated with integral bridge also discussed in this chapter.

Chapter 3: Present the formulation of finite element and infinite element of structure and surrounding soil media, it also present the load of integral bridge which has been taken in consideration in the analysis. The non-linear elastic model (Duncan 1970) and Winkler's model was discussed in details in this chapter. Explanation of the computer implementation (2-D finite element program) also discussed in this chapter.

Chapter 4: Presents the selection of case study and bridge dimension and load calculation for gravity, highway bridge live load and thermal expansion loads. Defined the finite element meshing and also the derivation of the soil parameters according to actual laboratory tests for Malaysian soil, and calculation of the Winkler spring constant. It also presents the results and discussion obtained from the analysis of integral bridge by using different techniques. Finally, presents the comparative study on different proposed models.

Chapter 5: Contains the conclusions and recommendations drawn from the research. Recommendations for future studies and research are given at the end of this chapter.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 What is an Integral Bridges?

An integral abutment bridge system is constructed without deck joints, particularly at the abutments. Integral abutment bridges have also been referred to as integral, jointless, rigid-frame and U-frame bridges. First built in the United States during the 1930s, integral abutment bridges have experienced extensive worldwide use in the 1990s.

Integral bridges can be single or multiple spans, and are built in an integral or a semi integral configuration. The superstructures of integral bridges are cast integrally with the abutments as shown in figure 2.2. Piers can be cast integrally or kept independent from the superstructure. In a jointless bridge, the backwall is integral with the superstructure and dimensionally the same as the diaphragms cast to the girders. This type of construction eliminates costly joints and sealers as well as maintenance costs associated with their use, resulting in a more economical and low maintenance structure and better overall rideability.

A slight modification of the integral abutment bridge is the semi- integral design, which eliminates joints, but still uses conventional bearings. However, unlike conventional bridges, the jointless slab protects these moveable bearings. Semi-integral bridges have end diaphragms that are integral with the superstructure, but non- integral with the foundation.

Semi- integral bridges require a horizontal joint separating the superstructure and the abutment. Stub abutments (short height), one type of semi- integral abutment, have worked well in limiting abutment cracking. Figure 2.1 shows examples of integral and semi- integral abutment designs.

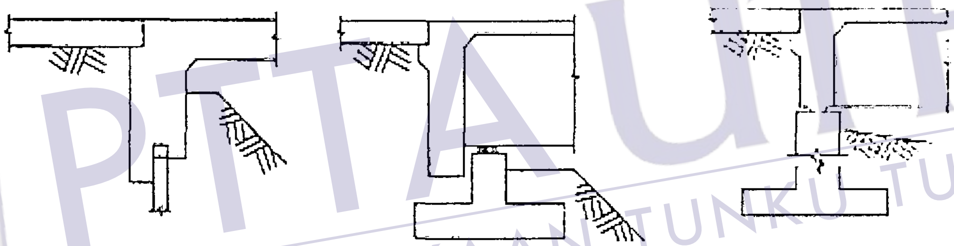

Figure 2.1: Integral and Semi-Integral Abutments

Integral or semi- integral bridges can incorporate precast concrete girders, cast-inplace concrete girders or steel girders. Precast, prestressed concrete experiences less thermal movement than steel and lower long-term movement due to creep and shrinkage than cast- inplace concrete. In moderate climates, concrete expands about 0.5 inch (13 mm) over a 100 feet (30.5 m) span length. Steel superstructures generally expand at twice this rate.

Approach slabs are generally used with integral and semi- integral bridges. Their primary function is to transfer the bridge movement to an open joint at the roadway interface. Sleeper slabs or grade beams are typically used to support the approach slabs at the roadway interface. In some instances, plastic sheets or similar materials are placed over the soil backfill beneath the approach slab to permit longitudinal movement when the superstructure expands or contracts. Mild reinforcement keeps the approach slab attached to the abutment and prevents the development of a crack between the slab and abutment. Typical approach slabs are about 20 to 25 feet (6.0 to 7.6 m) in length.

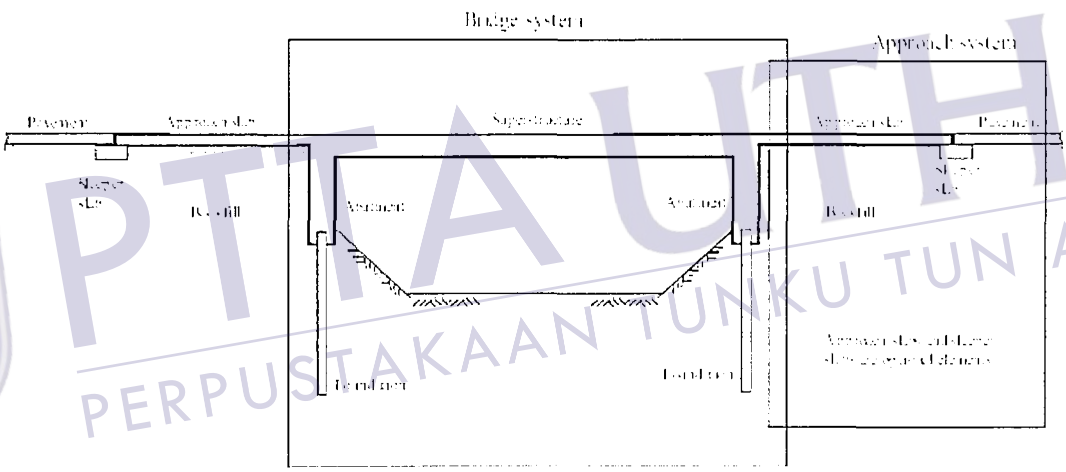

Figure 2.2: Integral Bridge Abutment System

Jointless bridges may not be completely jointless if the designers only change the number of joints and/or their locations. In addition, the continuity achieved by integral construction may introduce secondary stresses into the superstructure that could affect longterm performance and rideability. These secondary stresses could be due to thermal and moisture changes, gradients, concrete creep and shrinkage, or long-term subsoil consolidation settlement. Therefore, open joints are required at the end of the approach slabs to accommodate longitudinal movement of the superstructure. Expansion dams may also be used at midspan of long span bridges.

2.2 Characteristic of Integral Bridges

Integral abutment type bridge structures are simple or multiple span bridges that have their superstructure cast integrally with their substructure. Integral abutment bridges accommodate superstructure movements without conventional expansion joints. With the superstructure rigidly connected to the substructure and with flexible substructure piling, the superstructure is permitted to expand and contract. Approach slabs, connected to the abutment and deck slab with reinforcement, move with the superstructure. At its junction to the approach pavement, the approach slab may be supported by a sleeper slab. If a sleeper slab is not utilized, the superstructure movement is accommodated using flexible pavement joints. Due to the elimination of the bridge deck expansion joints, construction and maintenance costs are reduced.

The integral abutment bridge concept is based on the theory that due to the flexibility of the piling, thermal stresses are transferred to the substructure by way of a rigid connection between the superstructure and substructure. The concrete abutment contains sufficient bulk to be considered a rigid mass. A positive connection with the ends of the beams or girders is provided by rigidly connecting the beams or girders and by encasing them in reinforced concrete. This provides for full transfer of temperature variation and live load rotational displacement to the abutment piling.

The connection between the abutments and the superstructure shall be assumed to be pinned for the superstructure's design and analysis. The superstructure design shall include a check for the adverse effects of fixity.

2.3 Integral Bridge Elements

Integral bridges are consisting of many components, which interact with each other and with the environmental condition. Figure 2.3 shows the components of an integral bridge. An integral bridge generally comprises of deck slab, approach slab, abutment, wing walls, piers and foundation/piles. Since there are no expansion joints and bearings in an integral bridge, the abutment, its characteristics, design and construction would have a greater influence on overall behavior of the integral bridges compared to any other components. Therefore, a thorough study needs to be carried out on the behavior of this component.

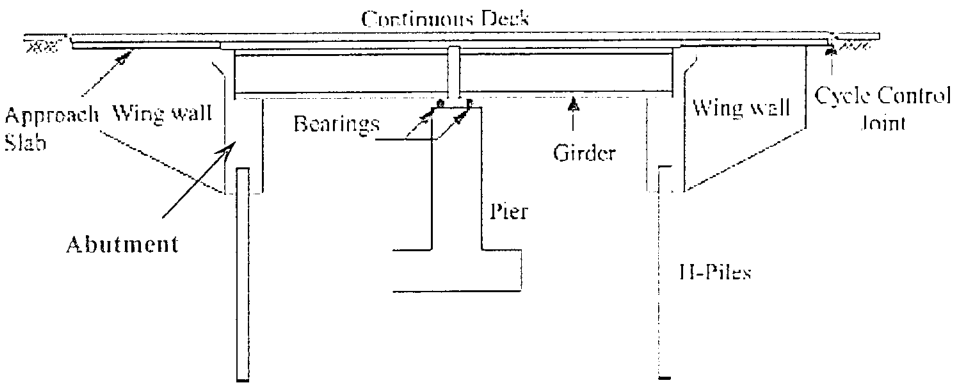

Figure 2.3: Integral Bridge Elements

2.3.1 Integral Abutment

In integral abutment bridges, the ends of the superstructure girders are fixed to the integral abutments. Expansion joints are thus eliminated at these supports. When the expansion joints are eliminated, forces that are induced by resistance to thermal movements must be proportioned among all substructure units. This must be considered in the design of integral abutments.

2.3.1.1 Type of Integral Abutments

a) Full integral abutment on piles

Figure 2.4 and 2.5 shows full integral abutment on pile full monolithic connection between end of superstructure and abutment. Single line of steel H-piles flex to accommodate thermally induced bridge deck movements. This is the most efficient design in most situations and every effort should be made to achieve full integral construction.

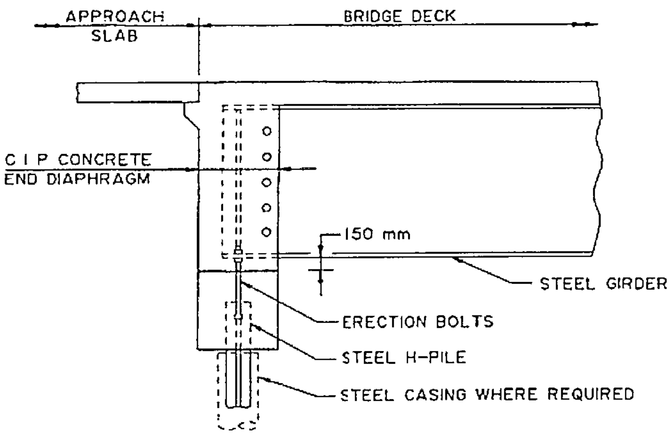

Figure 2.4: Full integral abutment on pile – Steel girder

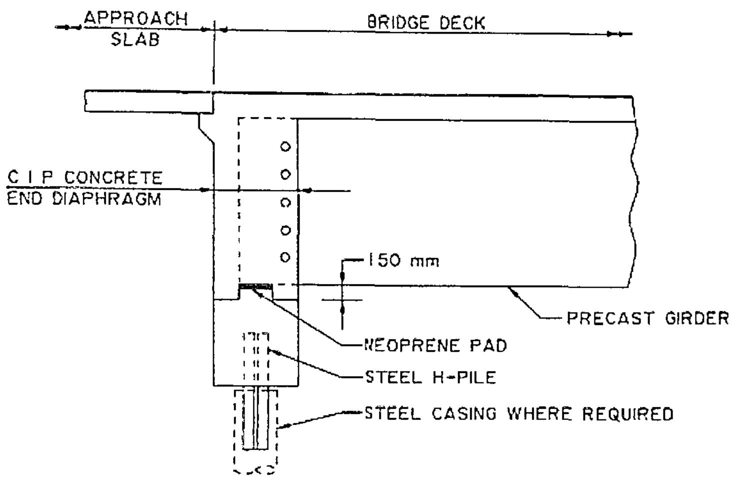

Figure 2.5: Full integral abutment on pile – Precast girder

b) Full integral abutment on spread footings

Figure 2.6 show full monolithic connection between end of superstructure and supporting footing. The full integral abutment on spread footing suitable for short stiff girders with small end rotation and expansion movements.

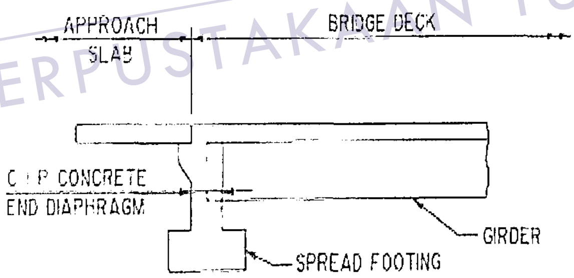

Figure 2.6: Full integral abutment on spread footing

c) Pinned-integral abutment

Figure 2.7 show pinned bearing between superstructure and abutment, where it is desirable to eliminate transfer of moments and rotations between abutment and girder ends.

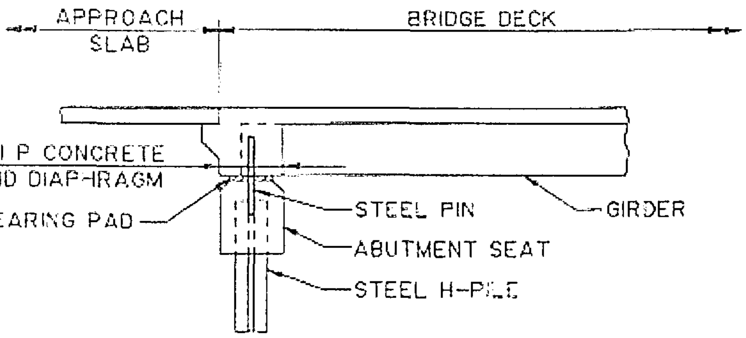

Figure 2.7: Pinned-integral abutment

d) Semi-integral abutment with sliding bearings

Figure 2.8 show the superstructure with no deck joints slides over fixed abutment seat, applicable where superstructure loads are too heavy for small flexible piles, or expansion movements are large, or foundation conditions do not permit flexing of supporting piles.

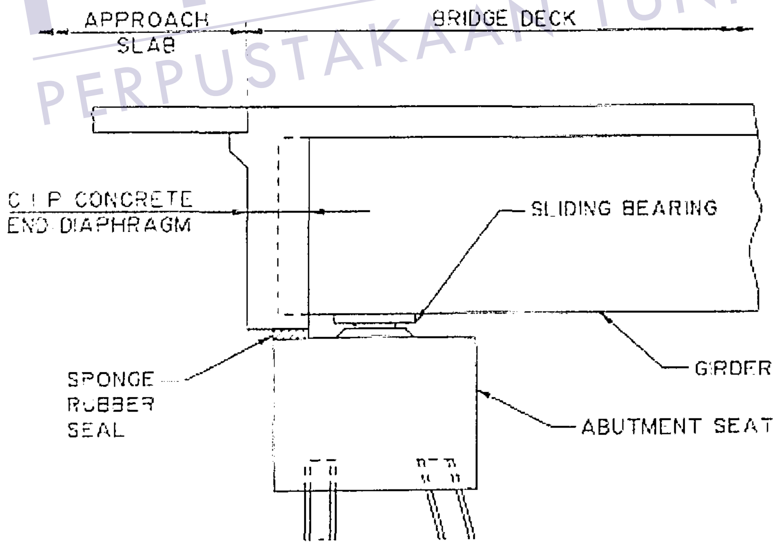

Figure 2.8: Semi-integral abutment with sliding bearings

2.3.2 Deck Slabs / Continuous Slabs

The deck forms the platform, which carries the traffic and distributes the live loads and dead loads to the supporting members. The deck slab can be either of concrete, steel or timber. The commonly used deck slab types are such as

- Reinforced concrete beams
- Pre-cast Reinforced Concrete Beams
- Pre-stressed Concrete Beam
- Reinforced Concrete Slab
- Voided Concrete Slab
- Concrete Box Girder
- Steel Beam and Concrete slab
- Post-tensioned concrete decks

2.3.3 Approach Slabs

Approach slabs will always be required for integral bridges. In the conventional bridge the soil behind the abutment is compacted against a rigid wall and should not settle significantly relative to the wall. Temperature-induced movements of the abutment cause settlement of the approach fill. If the soil behind the wall is too well compacted the pressure generated by this movements can dominant the design, but if the level of compaction is less then settlements will be larger. An approach slab can provide an effective method of transmitting movement strain from the deck into the backfill over a discrete length reducing the risk of the road pavement being damaged.

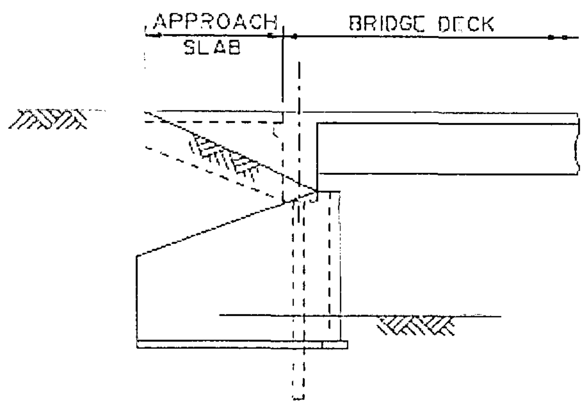

Figure 2.9: Approach Slab in Integral Bridges

2.4 General Aspects of Integral Bridges

Integral bridge concept is generously adopted and accepted by many states of US and UK. Several urban structures have been built in India in the recent past with this concept. However, no national standards or uniform policy regarding permissible bridge lengths, skews and design procedures have been clearly established, although certain general concepts become common in practice.

The advisory note BA 42/96 recommends that all bridges need to be integral if the over all lengths not exceeding 60m and skews less than 30°. The longitudinal movement in the bridge abutments is limited to ±20mm from the position at the time of restraint during construction. The integral bridges are designed for same range of temperature as the other bridges. The bridge spans and abutments are joined during construction at a temperature with in ±10°C. For concrete and composite decks, concrete with a coefficient of thermal expansion of 0.000012 per degree Celsius.

According to IAJB 2005 the range of design criteria for selection of integral bridge is summarized as below Table 2.1.

Table 2.1: Range of design criteria for selection of integral bridge

	Steel Girders	Concrete
Maximum span (ft)	65-300	60-200
Total length (ft)	150-650	150-1175
Maxim skew (degree)	15-70	15-70
Maximum curvature	0-10	0-10

2.5 Advantages of Integral Bridges

Some of the advantages of adopting Integral bridges over that of the conventional bridges are summarized below:

2.5.1 Simplified Construction

The simple characteristics of integral bridges make for rapid and economical construction. For example, there is no need to construct cofferdams, make footing excavations, place backfill, remove cofferdams, and prepare bridge seats, place bearings, back walls, and deck joints. Instead, integral construction generally results in just four concrete placement days. After the embankments, piles, and pile caps have been placed and deck stringers erected, deck slabs, continuity connections, and approach slabs can follow in rapid succession. In extreme cases, some multiple span integral bridges have been completed with just two concrete placement days; one for the structure itself and one for the approach slabs.

2.5.2 No Bearings and Joints

Integral bridges can be built without bearings and deck joints. Not only will this result in savings in initial costs, the absence of joints and bearings will reduce maintenance efforts. This is an important benefit because presently available deck joint sealing devices have such short effective service lives.

2.5.3 Reduced Life Cycle Cost and Long Term Maintenance

Integral bridges can be built without bearings and deck joints. Not only will this result in savings in initial costs, the absence of joints and bearings will reduce maintenance efforts. This is an important benefit because presently available deck joint sealing devices have such short effective service lives.

2.5.4 Improved Design Efficiency

Tangible efficiencies are achieved in substructure design due to an increase in the number of supports over which longitudinal and transverse superstructure loads may be distributed. For example, the load distribution for the bent supporting a two-span bridge is reduced by 67 percent when integral bridge rather than conventional bridges are used.

2.5.5 Enhanced Load Distribution

One of the most important attributes of integral bridges is their substantial reserve strength capacity. The integrity of their unified structural system makes them extremely resistant to the potentially damaging effects of illegal super imposed loads, pressures generated by the restrained growth of jointed rigid pavements, earthquakes, and debris laden flood flows.

2.5.6 Simplified Widening and Replacement Detail

As there are no expansion joint to match future widening is simple incase of integral bridges. When using multiple span integral bridges to replace single span structures with wall-type abutments, the great adaptability of integral bridges allows them to span across existing foundations, thus avoiding the need to remove them. Since small bridges are usually replaced in 50-year cycles, use of integral bridges with their simple pile foundations will considerably simplify future bridge replacements. The more durable integral bridges should help to increase the serviceable bridge age and extend replacement cycles by two or more decades.

2.6 Problems and Uncertainties Associated with Integral Bridges

Despite the significant advantages of integral bridges, there are some problems and uncertainties associated with them. These include the following:

a) Temperature-induced movements of the abutment cause settlement of the approach fill, resulting in a void near the abutment if the bridge has approach slabs. Traffic loads also contribute to approach fill settlement.

b) Secondary forces (due to shrinkage, creep, settlement, temperature and earth pressure) can cause cracks in concrete bridge abutments. Wing-walls can crack due to rotation and contraction of the superstructure.

c) Skewed integral bridges tend to rotate under the influence of cyclic changes in earth pressures on the abutment.

d) Bridge abutments can be undermined due to water entering into the approach fills at the bridge ends.

e) The piles that support the abutments may be subjected to high stresses as a result of cyclic expansion and contraction of the bridge superstructure. These stresses can cause formation of plastic hinges in the piles, and may reduce their axial load capacities.

f) The application of integral bridge concept has limitations. Integral bridges cannot be used with weak embankments or subsoil, and they can only be used for limited lengths, although the maximum length is still somewhat unclear. Integral bridges are suitable if the expected temperature-induced movement at each abutment is 51 mm (2 in.) or less and somewhat larger movements may be tolerable.

2.7 Thermal Bridge Displacements

A change in temperature causes a material to change in length. This fundamental property of materials is responsible for expansion and contraction of bridge superstructures. As the temperature increases, the bridge expands. As the temperature drops, the bridge will contract.

In conventional bridges, expansion joints exist between the superstructure and the abutment to accommodate these displacements. In integral bridges, the expansion joints are eliminated and the superstructure is allowed to freely displace the bridge abutments. Because of the abutment displacements, the pile and the approach fill are subjected to lateral loading and unloading.

2.7.1 Factors Affecting Bridge Temperatures

Structure temperatures at a locality are determined by continuously changing meteorological conditions. Although the meteorological conditions are very complex to fully understand, the primary factors that influence the structure temperatures can be summarized as follows.

- Diurnal temperature,
- Solar radiation,
- Wind speed,
- Precipitation,
- Thermal properties of structural material, and
- Other weather conditions.

Diurnal temperature variation is one of the most important parameters to determine the bridge temperature. Meteorological institutions throughout the United States measure the air temperature in a standard manner without being affected by wind and other weather conditions.

The solar radiation is higher in sunny days and lower in cloudy days. For all things being equal, higher solar radiation means higher structure temperature and lower solar radiation means lower structure temperature. Some of these stations measure solar radiation directly while some collect relevant meteorological data so that solar radiation can be indirectly determined.

The wind speed is an indication of how the temperature at a locality is affected by the temperatures at surrounding locations. In other words, the wind factor changes the temperatures at a locality. In general, higher wind speed translates into lower structure temperatures.

Precipitation is also an important factor because of the existence of heat transfer between the structure and the precipitation falling on the superstructure. Additionally, evaporation takes place, which reduces the heat stored in the superstructure, resulting in lower temperature. In general, precipitation reduces the structure temperature.

Thermal properties of the bridge superstructures are also an important factor because they control how the heat transfer takes place within the superstructure. Metals allow heat to flow faster than concrete does. For a given time and locality, structure temperature variation of metal bridges is higher than that of concrete bridges.

2.7.2 Bridge Displacement with Temperature

Bridge displacements are affected by both daily and seasonal temperature changes. Each daily variation in temperature completes a cycle of expansion and contraction, and the cycles repeat over time. The greatest expansion takes place during summer days, while the greatest contraction occurs during winter nights. These extreme temperature variations control the extreme displacements of integral bridges.

REFERENCES

1. Faraji, S., Ting, J.M. and D.S. Crovo. 2001. *"Nonlinear Analysis of Integral Bridges: Finite-Element Model"*, Jurnal of Geotechnical and Geoenvironmental Engineering: 454-461.

2. M. Dicleli and S. M. Albhaisi 2004, *"Performance of Abutment–Backfill System under Thermal Variations in Integral Bridges Built On Clay"* Journal of Engineering Structures 26 (2004) 949–962

3. M. Dicleli and S. M. Albhaisi 2003, *"Maximum Length of Integral Bridges Supported On Steel H-Piles Driven In Sand"* Journal of Engineering Structures 25 (2003) 1491–1504

4. M. Dicleli and S. M. Albhaisi 2003, *"Effect of Cyclic Thermal Loading on The Performance of Steel H-Piles in Integral Bridges with Stub- Abutments"*. Journal of Constructional Steel Research 60 (2004) 161–182

5. C. Spyrakosa and G. Loannidis 2003, *"Seismic Behavior of A Post-Tensioned Integral Bridge Including Soil–Structure Interaction (SSI)"*. Journal of Soil Dynamics and Earthquake Engineering 23 (2003) 53–63

6. .John S. Horvath, Ph.D., P.E.(2000). *"Integral-Abutment Bridges: Problems and Innovative Solutions Using EPS Geofoam and Other Geosynthetics"*.

Manhattan College Research Report No. CE/GE-00-2 New York, U.S.A. May 2000.

7. Arsoy, S; Barker,R. M.; and Duncan, J. M. (1999). "*The behavior of integral abutment bridges*", Virginia Transportation Research Council, Report No. VTRC 00-CR3, November 1999

8. Y. A. Khodair and S. Hassiotis (2005), "*Analysis of Soil–Pile Interaction in Integral Abutment*" Journal of Computers and Geotechnics 32 (2005) 201–209

9. P. Kumar T.V, D. K. Paul, R. Kumar and P. Agarwal, (2006), "*Behavior of Integral Bridges under Temperature and Seismic*" , Advances in Bridge Engineering, March 24 - 25, 2006

10. .S. Arsoy (2000), "*Experimental and Analytical Investigations of Piles and Abutments of Integral Bridges*", Faculty of the Virginia Polytechnic Institute and State University December 15, 2000

11. B.M. Lehane, D.L. Keogh, E.J. O'Brien (1999). "*Simplified elastic model for restraining effects of backfill soil on integral bridges*", Journal of Computers and Structures 73 (1999) 303- 313

12. P.N.Godbole, M.N.Viladhar & J.Noorazaei (1990), "*Nonlinear Soil-Structure Interaction Analysis Using Couples Finite-Infinite Elements*", Journal of Computer and Structures, Vol. 36, No. 6, pp. 1089-1096, 1990

13. J. S. Hovart (2002). *"Integral-Abutment Bridges: Problems and Innovative Solutions Using EPS Geofoam and Other Geosynthetics"*. Manhattan College. School of Engineering. Civil Engineering Department. Bronx, New York, USA.

14. R. J. Lock (2002).*"Integral Bridge Abutments"*, M.Eng. Project Report (June 2002), London UK

15. Department of Transport, Highways and Traffic (1989). *"BD 37/88: Load for Highway Bridges"*.

16. E. Roman, Y. Khodair and S. Hassiotis (2002).*"Design Details of Integral Bridge"*. Dep. Of Civil, Environmental and Ocean Engineering, Stevens Institute of Technology, Hoboken, NJ

17. R. Jayaraman, PB Merz and McLellan Pte Ltd, Singapore (2001). *"Integral bridge concept applied to rehabilitate an existing bridge and construct a dual-use bridge"*, 26th Conference on Our World In Concrete & Structures 26-28 August 2001, Singapore

18. P.N.Godbole, M.N.Viladhar & J.Noorazaei (1991) *"Soil-Structure Interaction in Plane Frames Using Coupled Finite-Infinite Elements"* Journal of Computer and Structures, Vol. 39, No. 5, pp. 535-546, 1991

19. George L. England, N. Tsang & D. I Bush (2000), *"Integral Bridges; A Fundamental Approach To The Time-Temperature Loading Problem"*, London Thomas Thelford.

20. Hambly, E. C. (1991), "Bridge Deck Behavior (2nd Edition) ", Bath: Chapman & Hall